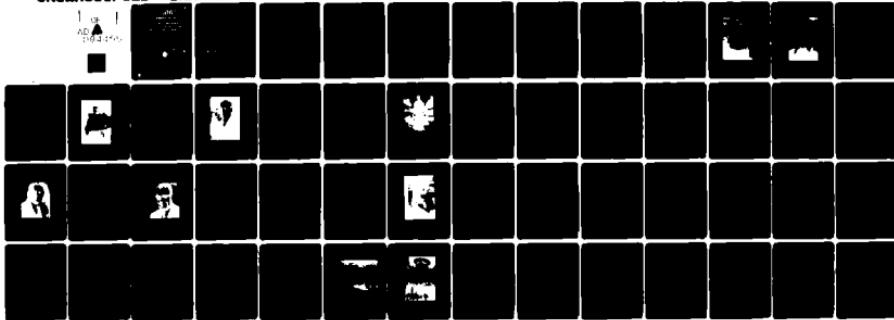


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AEROMEDICAL REVIEW

RECOLLECTIONS OF A DENTAL RESEARCHER

Fifty Years at the U.S. National Bureau of Standards: Interviews with George C. Paffenbarger, DDS

William R. Forrest, Colonel, USAF, DC

(Malcolm Grow USAF Medical Center,

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October 1980



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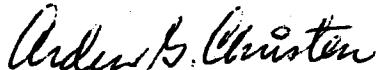
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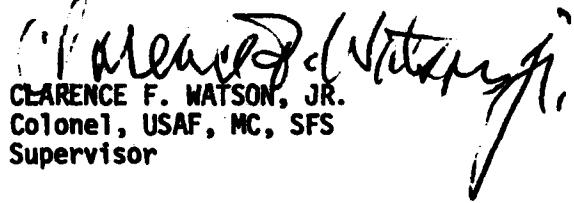
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This Review has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This Review has been reviewed and is approved for publication.



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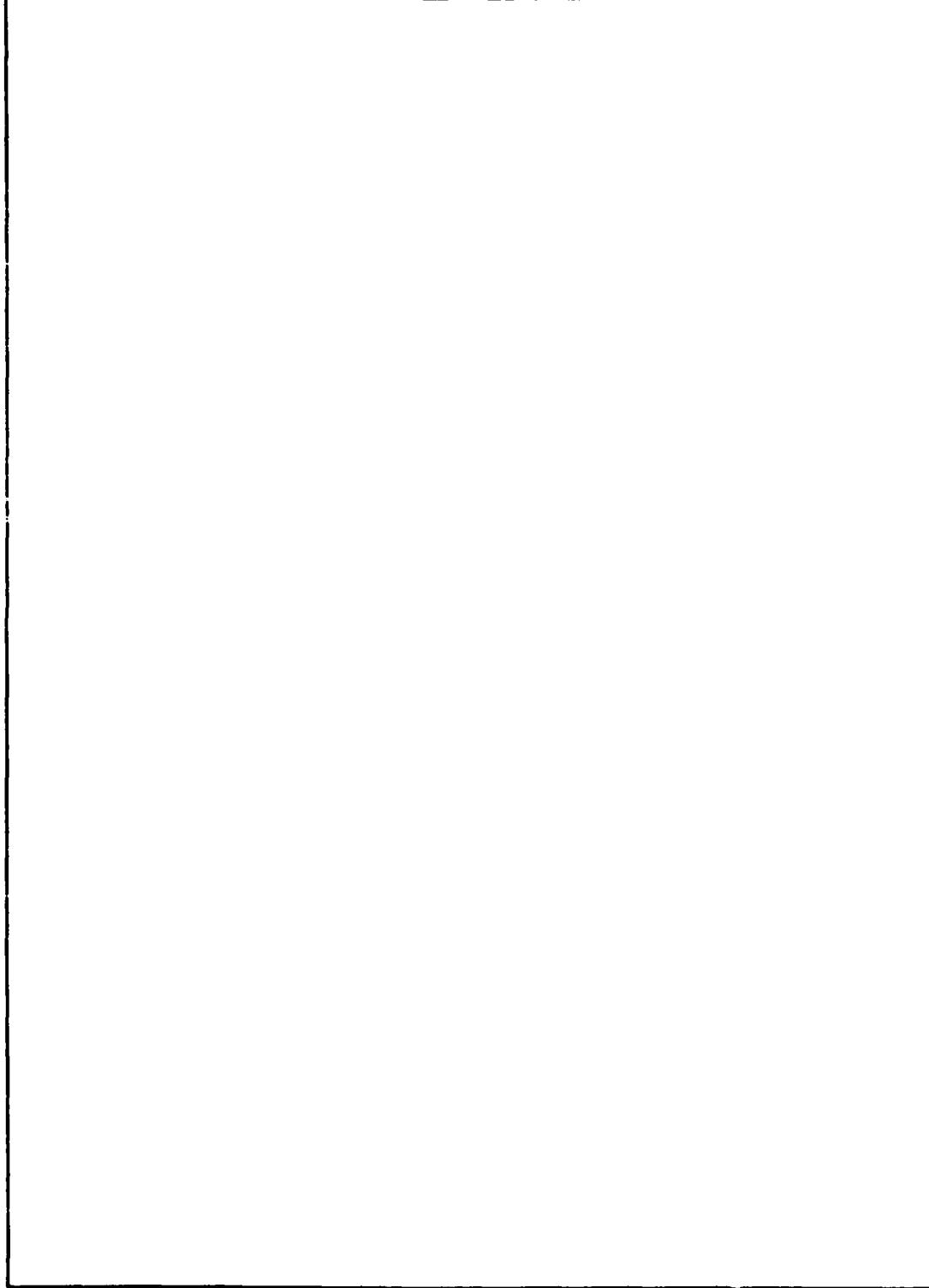
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is the life story of Dr. George C. Paffenbarger, DDS, as told in detail to the interviewers. Dr. Paffenbarger, a world-renowned researcher in dental materials at the National Bureau of Standards, Washington, D.C. (1929-1930), is a noted researcher and author of over 170 publications, developer of specifications for the American Dental Association, lecturer, and teacher. His contributions have revolutionized the concepts, ideas, and practices of dental materials in the military and civilian sectors.		

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PREFACE

In March 1978, the authors approached Dr. George C. Paffenbarger, DDS, world-renowned researcher in dental materials, and asked him to share his life story with the profession by means of an oral, tape-recorded history. The request was made at the Annual Meeting of the International Association of Dental Research (IADR) in Washington, D.C., where he presented a significant paper: "Dissolved Metal Content of Mercury Expressed from Copper-Rich Amalgam." After hearing our request, this modest titan of his profession agreed--somewhat reluctantly--to be interviewed. We had not previously met him, but he was well known to us through his fine reputation and striking appearance. His thatch of white hair and ever-present red necktie make him easily recognizable. (At one dental research meeting where he was given an award, everyone in attendance appeared wearing a red tie as a special tribute to him!)

Dr. Paffenbarger, although officially retired in 1968 from the U.S. National Bureau of Standards, still continues his daily work at the Bureau as Senior Research Associate for the American Dental Association (ADA). If he has slowed down, it isn't detectable. He has published over 170 papers, and his works continue to appear almost monthly in the world dental literature.

Dr. Nelson W. "Woody" Rupp, DDS, MS, Research Associate at the U.S. National Bureau of Standards, has ably summarized Dr. Paffenbarger's contributions to dentistry:

"When historians look over developments in dentistry from 1920 to 1980, Dr. Paffenbarger's imprint will be significant in many areas such as: precision casting of dental restorations, impression materials, dental amalgam, denture base materials, cements for luting restorations, esthetic restorative materials, and radiation safety for the patient, dental assistant and dentist. These historians, however, will be hard pressed to identify any developments which contributed more to improving dental treatment throughout the world than the specification-certification program. Through his efforts, the American Dental Certification Program has spread through the Federation Dentaire Internationale to the International Standards Organization (ISO). The dedicated work of Dr. Paffenbarger has led to the adoption of valid and respected specifications. This program became successful because he insisted on a careful selection of physical, chemical and mechanical property tests which would separate the products most likely to be clinically successful from inferior products. Without the ADA and ISO Certification Programs, each dentist would have to do his or her own testing of dental materials and equipment and their patients would become unfortunate guinea pigs.

"There is no one trait of Dr. Paffenbarger's which can be identified as the one characteristic responsible for his outstanding worldwide reputation. Among his unique and exceptional traits are his basic knowledge and understanding of the various dentally related physical and chemical sciences, aggressive inquisitiveness, integrity, persistent pursuit of excellence, and his warm, courteous, gentlemanly personality.

"Through these years of research on the composition, physical properties and appropriate handling techniques of dental materials, he has amassed a tremendous storehouse of knowledge. I believe he has retained every bit and is continuing to add to it through his insatiable appetite for facts and details. Many times when I am discussing a point, he will look at me with a slightly raised eyebrow, but not say a thing. As soon as I can, I will recheck the literature and sure enough, the raised eyebrow marked a questionable point. It is such a pleasure to be able to work with someone who demands complete and thorough work and does it in such a gentlemanly way. He is very approachable and there has never been a hint that one member of the staff is more important than another. Needless to say, these past 11 years that I have worked with Dr. Paffenbarger have been my most rewarding, and he has made it that way."

In short, this is the story of a remarkable man, told in his own words. It recounts his struggles and eventual success as a leader in dental research. Through the exceptional talents, the unselfish devotion to knowledge, and the professional foresight of Dr. Paffenbarger, every dentist and patient has benefited in some way. We are privileged to present his story.

ACKNOWLEDGMENTS

The authors wish to thank Ms. Ena Borden Shaw, Medical Editor, USAF School of Aerospace Medicine, Brooks AFB, Texas, for creative editing and patient counsel. This is the third and last of a series of oral histories, published as Aeromedical Reviews, in which we have both been involved. She is an exceptionally gifted, gracious individual who cares enough to "give her very best."

We extend a special "thank you" to Pamela J. Leahy, Dental Investigation Service, for her meticulous care in preparing the final manuscript. The junior author's daughters, Penny and Rebecca Christen, are commended for the many hours they spent in patiently typing and retyping the first five drafts during their weekends home from college. The respective assistance of Suzie Forrest and Joan Christen, wives of the authors, warrants special recognition and deep personal appreciation.

Finally, we would like to express our thanks to Dr. and Mrs. Paffenbarger for their warm hospitality while we visited their home, and for their complete cooperation throughout the entire project. They did not deny a single request. Certainly, Dr. Paffenbarger's story is an exceptional one. He has not been content merely to coast through life, conserving his energies. The author David Halberstam, in his book: The Powers That Be, captured this type of spirit, when he wrote--

"He did not want to go back and do conventional things, go to an office, make the allotted amount of money working the allotted amount of hours in the allotted office."

William R. Forrest
Arden G. Christen

CONTENTS

	Page
INTRODUCTION	5
THE FORMATIVE YEARS (1902-1920)	9
THE COLLEGE YEARS (1920-1924)	14
INITIAL YEARS IN PRACTICE AND TEACHING: RESEARCH OVERVIEW (1924-1929)	16
EARLY YEARS AT THE U.S. NATIONAL BUREAU OF STANDARDS (1929-1942)	24
NAVAL MEDICAL SUPPLY DEPOT (1942-1946)	28
OVERALL PHILOSOPHIES (1924-1980)	34
REFERENCES	44
INDEX OF NAMES CITED IN TEXT	48

Figures (Photographs)Figure
No.

1. George C. Paffenbarger, DDS, at 76 years of age	6
2. George C. Paffenbarger, fixing the old stone fence in front of his farmhouse in Maryland	7
3. George C. Paffenbarger at about 8 months of age in McArthur, Ohio.	10
4. Andrew Wolfe Paffenbarger, DDS, father of George C. Paffenbarger, at 65 years of age.	12
5. George C. Paffenbarger, 21 years of age, while a Junior student in Dental School, Ohio State University	15
6. Dr. William Souder (1884-1974), physicist and noted dental researcher for the U.S. National Bureau of Standards.	23
7. Dr. Norris Onslow Taylor, first Research Associate from the American Dental Association at the U.S. National Bureau of Standards	25

CONTENTS (Cont'd.)

<u>Figure No.</u>		<u>Page</u>
8.	Dr. Paffenbarger (in 1929) measuring the thermal expansion of dental investment.	29
9.	Luis Echeverria, President of Mexico, presenting the International Miller Award to Dr. Paffenbarger at the opening ceremony of the 15th World Dental Congress and the 60th Annual Session of the Federation Dentaire Internationale (FDI), Mexico City, Oct. 22, 1972, while Dr. Harold Hillenbrand, President of the FDI, looks on. . . .	42
10.	Rear Admiral George C. Paffenbarger, Washington, D.C., June 13, 1968	43

RECOLLECTIONS OF A DENTAL RESEARCHER

Fifty Years at the U.S. National Bureau of Standards: Interviews with George C. Paffenbarger, DDS^{1/}

INTRODUCTION

The oral history of Dr. George C. Paffenbarger (Fig. 1) was compiled from two interviews, taped on Dec. 5, 1978, and Aug. 26, 1979, respectively. During the second of these sessions, the interviewers sat on the Doctor's shady front porch, sipping mint tea and consuming bourbon-flavored dessert. Tall rows of corn almost ready for harvest stood nearby. It was a muggy Sunday afternoon--a truly pastoral setting, with the sounds of buzzing insects and chattering birds surrounding us. It was a time for nostalgia and remembering.

The Paffenbarger family had just sold their farm and were about to move back to the city following 33 years of rural life. After several hours of steady conversation, we took a leisurely tour of the farm, inspecting buildings, foliage, fences, and trees, while we reviewed the significant accumulated events of a lifetime. One of the large walnut trees, a splendid specimen, was especially admired. Dr. Paffenbarger proudly announced that the family had been offered \$500 for this tree but, for sentimental reasons, "spared the axe." Dry fieldstone fences were in evidence all around the homeplace. A plaque, affixed to one of the stones on the fence in front of the house (Fig. 2), announced that the fence had been rebuilt by Mrs. Paffenbarger's father, Mr. H. M. Appleman, between 1953-1954, when he was 82 years old.

This 130-acre farm in suburban Maryland (about 30 miles, as the crow flies, from downtown Washington, D.C.) is situated in rolling picturesque countryside. The property is entered by a pleasant, narrow lane and is identified by a modest sign, "Mother's Good Will," painted on a piece of elm wood. The name was chosen, several years ago, from an old deed to the property; for the historic farm had been included on a local historical tour and a name was needed for public relations reasons.

^{1/}EDITOR'S NOTE: Dr. A. G. Christen has also prepared several related publications, based on in-depth interviews with two National Dental Consultants, entitled: Portrait of a National Dental Consultant, Life Story of a Prevention-Oriented Dentist: An Interview with Miles R. Markley, DDS, SAM Aeromed Rev 1-78, Oct. 1978; and A Modern Pioneer in Preventive Dentistry--Sumter S. Arnim, DDS, PhD, Teacher, Researcher, and National Dental Consultant: An Interview, SAM Aeromed Rev 1-79, June 1979.



Figure 1. George C. Paffenbarger, DDS, at 76 years of age, photographed on Aug. 26, 1979.



Figure 2. George C. Paffenbarger, fixing the old stone fence in front of his farmhouse in Maryland, Aug. 26, 1979.

The Paffenbargers, with their three teenage children, moved to this farm from Brooklyn right after World War II.^{2/} The main part of the house was built in the late 1700's. After moving in, the Paffenbargers uncovered an old fireplace. They sawed out a 4 x 6 ft. section of the floor and made stone steps down the sunken fieldstone hearth. For the first winter and a half, they lived in this house in true pioneer fashion (e.g., no electricity, and no indoor bathroom). They used kerosene lamps, candles, one or two gasoline lamps, a large woodburning stove in the kitchen, and little woodburning stoves in the bedrooms. After the War was over and some of the shortages ceased to exist, the Potomac Electric Power Company was able to get poles and wire to electrify the farms in that district.

Later, the Paffenbargers raised 150 hogs, 75 sheep, and 12 milk cows. All of the children learned to milk. They also learned to cultivate the fields, using a surplus Army jeep, second-hand discs, and rickety seeding machines. Since the family had never butchered or cured meat before, they obtained descriptive "how-to-do-it" handbooks from the government, and borrowed a scalding trough and other equipment from the neighbors, who pitched in to teach these "city slickers" about the country ways. Every four or five years, the family would become marooned by snowdrifts; but they managed to survive all of these difficult times.

^{2/} Mrs. Marion P. Kumpula, Secretary to Dr. Paffenbarger beginning in 1952, and later his Administrative Assistant until his retirement, writes:

"When Dr. Paffenbarger returned to the National Bureau of Standards following his three years in World War II, he purchased a Maryland farm of over 120 acres, with a tenant house, and farmhouse in deplorable condition. He and his family worked diligently to restore both the land and the houses. Dental self-curing resin came in handy to fill the cracks in the floors. There was a lovely, comfortable home filled with mementos of their many trips abroad and with gifts from their foreign friends. His home was open to the staff, just as it was to strangers. 'Paffenbarger Punch,' a concoction of fruit juices and several heavier liquids, became famous around the globe. For many years the Paffenbargers invited the staff and their families to a Fourth of July picnic and fireworks display, with George as the official fireworks lighter. He did so with such glee (supervising the children with firecrackers and sparklers) that we all suspected he had these pyrotechnic parties for his personal pleasure.

"He loved the farm. Each rock, tree, fence, or plant seemed to have a story connected with it. He delighted in mounting his tractor to plow, mow, haul, push, clear--whatever the land demanded. He would often hitch a farm trailer to the tractor and take his guests on a very bumpy ride down the lane, across the fields, through the bluebells or other seasonal flowers, to the creek that ran through his property. They would have a picnic in the shade of the trees on the bank of the creek. . . an idyllic day.

"One amusing episode involved an unexpected snowstorm. We and another couple, Al and Florence Forziati, had been invited to Paffenbarger's for dinner, first, and a square dance afterward, later. It began to snow rather hard late in the afternoon and, as I was coming down with a cold, I phoned our regrets. The Forziati's braved the snow and remained as houseguests due to a blizzard. The fuel-tank gauge at the house read nearly empty; the tractor was snowed in; so the men decided they would have to cart oil from the unoccupied tenant house, over a third of a mile, on foot. One man convinced these men, if not very tall stature, mushing through the drifted fields bearing five-wheeled oilcans in an effort to keep their ladies warm. They would restore themselves with Paffenbarger punch by the sunken fireplace in the living room. It was this time before the county plows could rescue them, but it was a lot longer before George Paffenbarger tired admit to Al Forziati that his hard labor had been unnecessary. The gauge on the fuel tank was faulty. There had been plenty of fuel. . . if only those eminent scientists had thought to put a wooden stick in the tank!"

THE FORMATIVE YEARS (1902-1920)

FORREST: Would you describe your childhood years?

PAFFENBARGER: I was born in McArthur, Ohio, Nov. 3, 1902, and my parents christened me George Corbly Paffenbarger. Corbly was my grandmother's maiden name (Fig. 3).

FORREST: Were you an only son?

PAFFENBARGER: No, I have a brother who is nine years older. (He is now a retired Professor of Engineering at Ohio State University.) We had two elder sisters who died in infancy. In many ways, I truly was an only child because of the nine years difference between us two boys. My brother went off to college in 1911, when I was only nine years old. So, from then on, I was an only child in the family. I came from a rural Appalachian village in south-central Ohio called McArthur, with a population of around a thousand. My father was a dentist there. He was raised on a farm about three miles north of this village. It's the poorest county in Ohio, which is a very populous state--I think the present population for the whole county is something around 9,500.

The country is hilly and wooded, with very little farmland. But of course, when my father was born in 1856, farms were all over the place. Many of them have now been abandoned. In fact, the county has been losing population steadily since 1870. We had a big garden, at least a half an acre; and I helped with that.

CHRISTEN: What type of school or church activities were you involved in when you were a youth?

PAFFENBARGER: I always seemed to be active and outgoing. The only athletic team we had was basketball, and I played all four years on the team as a guard. In our little village, basketball was the sport then. I was president of the senior class. With 26 students, it was the largest graduating class our village had ever had.

I was a good student because my parents saw to it. I had to bring my books home; and my mother would drill me in spelling, English, history, and geography. Every night I would have to tell her what my lessons were for the following day and she'd quiz me. In this way, of course, I seemed bright to the other students, because most of them didn't have someone at home beating the studies into their heads.

In high school and at college, I was always the first in my class simply because I had had study habits drilled into me. I just had average intelligence; but with this industriousness and strong desire to excel, there was no way to keep me down. In school and church, I frequently had to memorize and deliver poetry and other recitations. With this background, presiding at meetings or speaking in front of a group has never been a great task for me.

FORREST: Tell us more about your father.



Figure 3. George Corbly Paffenbarger at about eight months of age
McArthur, Ohio.

PAFFENBARGER: Any small community always has few leading families. In our community, my dad was a highly respected dentist (Fig. 4). He practiced dentistry in McArthur from 1883 until 1943--some 60 years. For 50 of those years, he was the only dentist in the whole county and served approximately 12,000 individuals. He was 87 years old when he finally quit treating patients, and he died at age 93.

My father was also a founder and the Director of the Building and Loan Association. He was on the Board of Education for about 10 years. He belonged to every Lodge in town (including the Masonic, Rotary, Woodmen of the World, the Knights of Pythias, and the International Order of Odd Fellows), always serving as some type of officer. My father taught a girl's Sunday School class for 15 years; and when they built a new church in McArthur, these students (now women) purchased a great big stained-glass window to be inscribed with his name. In the Methodist Episcopal Church, he was on the Board of Trustees, and he owned most of the telephone company.

CHRISTEN: How would you describe the child-rearing philosophies of your parents?

PAFFENBARGER: My parents were strict disciplinarians. They were firm, practicing Methodists who frowned upon dancing and cardplaying. No alcohol was allowed in our home, and tobacco use was forbidden. (They had better not find any of their youngsters involved with any of these "vices," either!) My father was an unusually even-tempered individual and his discipline was mostly verbal. But he could talk to me and have me in tears in just a short time. His language wasn't rough or gruff; but his words, spoken in a quiet voice, had a tremendous effect upon me.

He never quarreled with anybody nor got into any lawsuits nor disputes with townspeople. Mother was the one who exercised the corporal punishment. If we didn't "mind" her, we got switched. (That is, until we were large enough to run away from her, and then she couldn't catch us!) Mother was an unusually dedicated person. She had no interests in life other than her family. Her family came first, as far as she was concerned; and, for her children, there was no sacrifice she would not make. In retrospect, I'm really glad that we had such discipline within our family. Our parents' example set a pattern for us to follow in later life. Of course, this guidance doesn't seem to be effective in all families. Sometimes children go astray in the best of home situations--possibly because of genetic factors. Our homelife, however, was very pleasant; and I look back upon it with increasing reverence to both of my parents for a fine upbringing.

My father had not only a highly developed sense of integrity and honesty, but also a good judicial mind. One time, my brother took me to the little roller-skating rink in our town. A girl there offered me some candy, and afterward put her coat in the row ahead of me with the remainder of the candy in a pocket. Because she wasn't around and temptation overcame me, I decided I would help myself to a few more pieces of candy. Someone saw me and told my brother. He was dumbfounded that I was so dishonest--a common little thief! He took me home and "spilled the beans" to my dad, and I'll never forget the quiet, intense situation I had with him discussing the importance of honesty. I straightened out in a hurry. It was drilled into me early in life that I shouldn't do anything that would shame my parents.

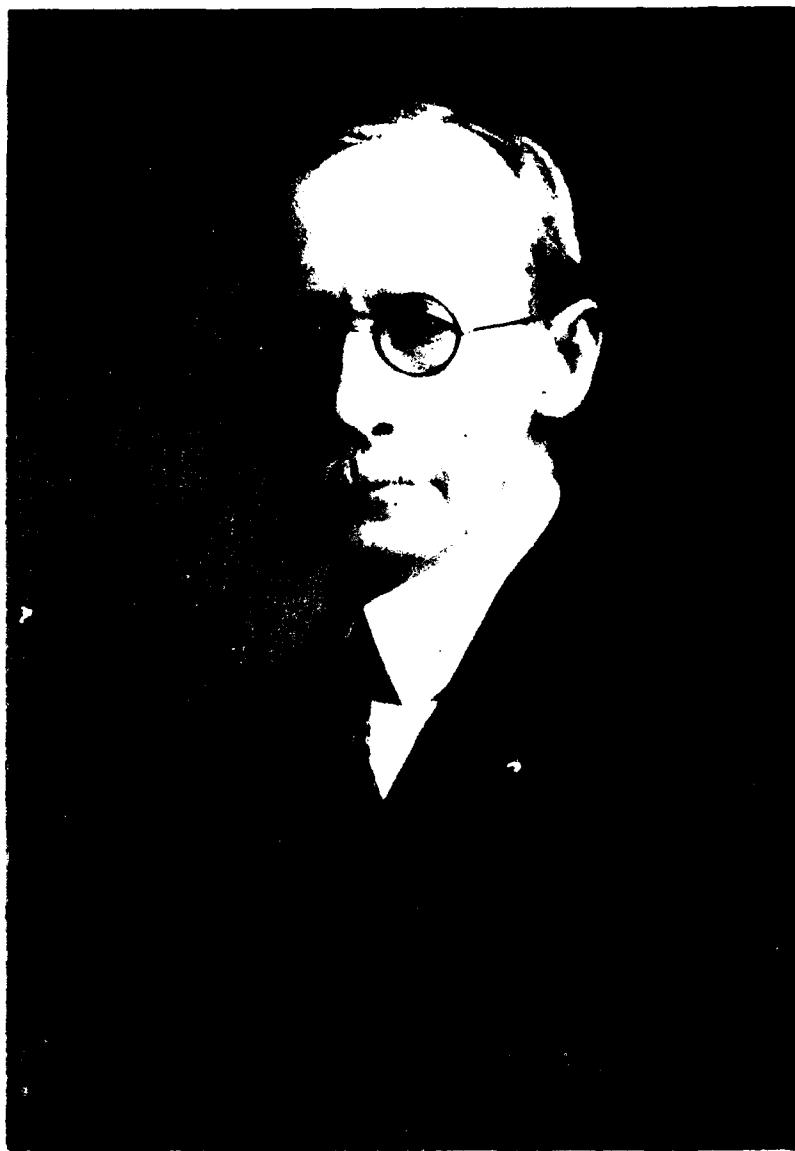


Figure 4. Andrew Wolfe Paffenbarger, DDS, father of George C. Paffenbarger, at 65 years of age (about 1920). Dr. A. W. Paffenbarger practiced dentistry in McArthur, Ohio, for 57 years.

CHRISTEN: What role did your father play in your becoming a dentist?

PAFFENBARGER: A combination of factors determined the matter. Dad wanted my older brother to become a dentist, but he decided on engineering. I can't recall if dad ever asked me if I would want to be a dentist, but I did get to work in his office. My father wasn't much for putting pressure on his children concerning such matters, but he said that I could observe what he was doing and help in the laboratory. I became acquainted with dentistry and saw him extract teeth, as I was right there at the chair to see what he was doing. I wasn't afraid of the sight of blood. He used a general anesthetic for his oral surgery, since local anesthetics were not any good at that time. They did use cocaine during those days for infiltrating around teeth, so he was required to have a narcotics license. The general anesthetic he used, as I recall, was of a mixture of methyl bromide, ethyl bromide, and ethyl chloride. He put a leather bag over the patient's face and then broke ampules of the mixture of these liquids inside the bag. The mixture produced a very rapid induction and equally fast recovery period, but dad was pretty fast with forceps. In those days, dentists used general anesthesia without any formal training whatsoever, except for listening to the sales pitch of the detail man. To the best of my knowledge, he never had any kind of accident or serious incident in all those years of practice.

In the laboratory, I would take the wax dentures (after he had made them on the simple articulator), invest them in the flasks, and then separate the two halves of the flask and boil out the wax. We saved all that wax, heating it just enough so that I could pull it out relatively intact. Later, I would pack the rubber in the flask. We had pink rubber for the veneer--and dark maroon, or a better quality olive-colored base rubber, for the palate. If the labial and buccal flanges were thick enough, we used olive-based rubber on the back and pink-tinted rubber on the front. We had a large block of warmed granite which we used as a work surface to heat the strips of denture rubber. Of course, plaster molds were lined with burnished tinfoil.

After the rubber was packed and trimmed, I would vulcanize it in a type of autoclave they had then. This autoclave was an upright type that had a little pop valve in it so that, if pressure rose too high, the valve would blow out of the diaphragm. The autoclave had a gauge so that one could read the pressure. (I can't remember the time-temperature-pressure cycle we used.) Since we didn't have artificial stone in those days, we used ordinary wall plaster. This plaster disintegrated during vulcanization because we carried it to a high temperature. Then I would dig out the vulcanite denture, clean it up, and polish it for my father. I did all of that kind of work.

We would save all that wax until we had a whole bucketful. The wax would have a lot of plaster chips, dirt, and everything else in it. We would put the wax in a bucket of water containing boric acid, and then melt the wax. All of the light impurities would come to the top and we'd skim them off. The heavy particles would fall to the bottom. I would then dip a little piece of thin plate glass, about 3 x 6 in., into the molten wax (like dipping a candle) and pulled it out. As the wax started to cool I would trim off the edges with a knife and stick the wax-covered plate glass in cold water. Presto, an instant sheet of base-plate wax! We hardly ever bought anything at a dental supply company. We did all our own work and wouldn't think of sending anything out to the laboratory.

THE COLLEGE YEARS (1920-1924)

FORREST: Through some of the detective work we've been doing, we discovered that you graduated from Dental School at Ohio State University with highest honors in 1924. What was your dental education like?

PAFFENBARGER: At that time, there was only a four-year curriculum in dentistry. I was the last of the four-year graduates, having graduated from high school in 1920. After that, one year of pre-dental college training was required, and soon thereafter two years of pre-dentistry were required for admission to dental school. Now, about 80% of dental graduates have a baccalaureate degree prior to seeking their doctor's degree in dentistry.

I was a very serious dental student. In fact, I worked too hard. Frankly, I was scared to death! I had just come out of a dinky high school, and suddenly I was hit with zoology and comparative anatomy. I spent every weekend studying anatomy, and I'd be in front of the building Monday morning before the janitor opened up. I guess my fear was stimulated by the way students were being taught in those days. I vividly recall the first time we went to our anatomy class and heard our gruff instructor's introduction to the course:

"Well, I've got a lot of people in this class and most of you have been spoon-fed. You've been spoon-fed in high school and by your parents; but do you know what's going to happen in this class? I'm going to jerk that spoon out of your mouth. There's no doubt about it, 40 percent of this class probably won't get through it. When I'm lecturing, I want to see everyone work. I don't want to see any of your faces---I want to see you taking notes."

And he really meant it. We started out in dental school with 120 students and graduated only about 60. Somehow, I was able to finish first in my class (Fig. 5).

We had very poor accommodations then. Ohio State University had formerly been a proprietary school, the Dental Department of Ohio Medical University. (I think that Ohio Medical University became an integral part of Ohio State University around 1911-14.) We had a very large clinic floor, but no motorized equipment of any kind. We did all of our cavity preparations and all of our crown and bridge preparations with the foot engine. We didn't have running water with cuspidors, or anything of that nature.

You would be very much surprised at the prosthetic techniques that we used. We made what was called a Watts-Metal Lower Denture. A wax pattern of a lower denture base was made on a gypsum cast, invested, dewaxed, and cast in a fusible alloy (Watt's Metal). The current theory was that this heavy metal base would help hold the lower denture in place. We did a set of complete dentures. We also made a die and a counter-die out of the appropriate fusible metals. Then we would swedge a german silver blank to fit the cast, trim it to contour, solder a rim on the periphery and a framework on the metal base. To that framework was affixed a set of soldered porcelain teeth with the roots on them and with a platinum lug that could be soldered to the framework. In actual practice, this prosthesis was called: a continuous gum denture using platinum throughout (instead of german silver, as we did in the technique laboratory). Porcelain was fused to the pink portion around the teeth to form this denture. We also made aluminum maxillary dentures in which the base was cast out of aluminum.



Figure 5. George C. Paffenbarger, 21 years of age, while a Junior student in Dental School, Ohio State University.

[Photographed when he was attending an ROTC camp with 250 college students at Carlisle Barracks, Pa. (June 13-July 25, 1923). The camp was on the grounds of the old Carlisle Indian School, where Jim Thorpe had played on the famous Carlisle football team. In 1918, Carlisle ceased to function as a Department of the Interior Indian School and was transferred to the War Department. Carlisle then became the Medical Field Service School of the Army.]

All of our inlays and other types of castings were cast in what we called a "Cowbell." It really was an inverted cowbell with an attached chain and handle. When the aluminum was completely melted with a bunsen burner, we simply swung around the cowbell by hand and cast this aluminum base for an upper denture. (I cite that to show you how primitive our technique courses were!) We designed partial and complete dentures, constructed a vulcanite, with wire clasps and bars for the partial dentures. I had an advantage over other students because I was already familiar with some of these techniques, as I had worked in my father's dental office.

No dental research at all was then being conducted at Ohio State University.

INITIAL YEARS IN PRACTICE AND TEACHING:
RESEARCH OVERVIEW (1924-1929)

FORREST: I suppose that it was only natural that you would become associated with your father in the practice of dentistry after your graduation from Ohio State University.

PAFFENBARGER: For 8 months after graduation I practiced with my father, and I learned a lot about dentistry. Of course, my dad and I had somewhat different ideas. When I was practicing with him, he had never had an x-ray machine because there wasn't enough money to buy one. Another dentist, who had an x-ray unit, moved to town; and I sent my patients over to him when I needed dental radiographs. (In those days, there was no professional antagonism at all, and dentists cooperated a lot with each other.)

My dad used a rubber dam whenever he put in a gold foil, but he never used rubber dams for anything else. He used cotton rolls, and didn't even have a saliva ejector. Since his office lacked water and sewer connections, he had a cuspidor for his patients. He had to pour water into the cuspidor. Underneath it was a collecting receptacle that he'd empty from time to time in the street. My dad never cast an inlay, so he referred patients needing inlays to me. He made shell crowns out of coin gold. When it came to extracting teeth, however, he could really run circles around me.

In some ways, dad was ahead of his time. He used a mechanical mixer to prepare amalgam. After it was mixed, he'd put it in a dappen dish--and never touched it with his hands. As a result, his amalgams held up well. The other dentist in town used to mull his amalgams in his palms, a standard practice of the day. He had clammy hands to begin with, and the perspiration was like salt water. It really affected those zinc-containing amalgams. The oxygen which was liberated combined with the metal to form black oxides; and the hydrogen gas accumulated, causing the porous amalgam to bulge out of the cavity. Much later, I published a paper from the U.S. Bureau of Standards showing what would happen if one palmed the zinc-containing alloy (28). We even made a motion picture showing what happened. Anyway, I practiced in McArthur from June 1924 to February 1925, when I developed severe pulmonary hemorrhages. The local physician's diagnosis was "galloping consumption." So I had to stay in bed for a few weeks until we got the hemorrhages to stop.

Prior to this time, at the University, I had met a freshman dental student--Rachel Appleman--and we became engaged. After I graduated, I went down to

practice with my father, and she went on to finish her studies at the University in the Department of Education.

When I developed these hemorrhages and couldn't practice, I went to Columbus for additional treatment; and I became, seemingly, quite well again. I wondered what I was going to do then. So much of life depends upon chance and circumstances. The next development in my life illustrates this statement in graphic manner.... Dennis Steele was a man who owned a hardware store in my hometown. His son, Percy, went to tiny Rio Grande College and played football. He eventually went to the Miami University (Oxford, Ohio) and to Harvard University (Cambridge, Mass.) to play varsity football. In fact, he was on one of the Harvard championship teams and played in the Rose Bowl. When I went back to practice in my hometown, he also came back to run his dad's little hardware store after his father's death. Percy wasn't satisfied there, so he sold the store and went over to Honolulu. I wrote to ask him if he knew of any openings in Honolulu. As it turned out, Percy's dentist was one of the directors of the Palama Settlement Dental Clinic (the Strong-Carter Dental Clinic now), which needed another dentist. So they hired me; Rachel and I married, and we went to Honolulu so that I could work as a pedodontist in the Palama Settlement Dental Clinic.

Well I didn't exercise good judgment. I vigorously surfboarded, played volleyball, swam, and hiked in the mountains; within four months, I came down with some terrific pulmonary hemorrhages. I was kept in Queen's Hospital for one month, lying flat on my back. After the hemorrhages stopped, I was transferred to Leahi Home, a sanitarium for tuberculous patients. I was there for another ten months until I was discharged. In the meantime, my wife had been teaching school in the winter months and serving as a bank clerk in the summertime. We lived in a little apartment. Then I developed gastric trouble. I couldn't eat anything. I would wake up retching in the middle of the night with dry heaves. I went down to a clinic, where I was diagnosed as having a duodenal ulcer. They wanted to operate on me. Well, we'd been away from home for a year and a half, and we were nearly broke. I went up to see the head physician, Dr. Sinclair, at Leahi Home. He told me that he had had stomach trouble at one time and that they had wanted to operate on him also. He advised me: "Don't let them operate on you. Instead, go to the Sippy Clinic in Chicago."³

We took his advice. When we arrived in Chicago, Dr. Sippy wasn't there; but his assistant, Dr. Drenen, took me in and told me he was pretty sure that I had either a gastric or duodenal ulcer. He gave me some Sippy powders and advised the following regimen: milk on the hour, and a Sippy powder every half an hour. He told me that the Sippy diet would make my stomach alkaline, that the pyloric valve therefore wouldn't close, and that I wouldn't have any retained acid in my stomach. I promised to return to their clinic after Christmas vacation. When I came back, I was put in the Mercy Hospital for a month. There, they gave me the Sippy treatment and also pumped my stomach every evening. They taught me to do this myself. Then they discharged me, and said I was to evacuate my stomach with this pump every evening to eliminate any residual food in my stomach at night. So I did as I was told for about a year.

³Herbert Merton Sippy (1866-1921) was an American physician who developed a regimen of treatment of peptic ulcer based on neutralization of hydrochloric acid by frequent feedings and the use of alkalies in relatively retarded but adequate quantities.

On the way home from Chicago, I met a Dr. Harvey Cottrell who was not only Head of the Prosthodontic Department but also a former mentor of mine at Ohio State University. I was telling him my sad tale when he said: "What are you going to do?" I replied: "I don't know. I don't know what I can do." He said: "I'd like to have you come to teach in my Department." I had nothing else better to do, so I decided to look into the situation. But, when I arrived at Ohio State, the Dean of the Dental School had changed plans--I was now going to teach operative dentistry.

I said to him: "First, I must find out if I'm physically able to teach." I went to a chest physician, a Dr. Benson, who fluoroscoped me. He told me that I could work, but only half time. He also required that I stay in bed during the time that I was not teaching at the University. I did as he directed, and went to see him every month. After a period of time, I was allowed to work full time. So that's the story of how I went into teaching at Ohio State University.

CHRISTEN: Which of the pioneer dental researchers of those days influenced thinking the most in dentistry?

PAFFENBARGER: There were a number of great dental researchers. Dr. G. V. Black was, of course, the premier researcher in dentistry. If you have ever read his biography by his sister and brother, I'm sure you will appreciate what an unusual person he was (13).

In his youth, Black was what one might call an "errant person." When they put him to plowing a field on the farm, he would plow one or so furrows and then he might see an oak tree. His curiosity would get the best of him and he was compelled to examine that oak tree. He would study its leaves, and look at the other nearby oak trees and do the same. He was always interested in understanding the intricate details of his surroundings, rather than attending to the chores to which he had been assigned. In fact, he didn't do at all well in school. He was a problem for his parents. So they sent him to his brother, a physician, hopefully to straighten him out. There he became apprenticed to become a dentist. But he was never satisfied. He began to experiment with the microscope. He began to wonder about the inner workings of everything around him.

Black was a meticulous worker and self-taught person. He became an authority in pathology, operative dentistry, dental materials, periodontal therapy, and dental caries.⁴ Of course, much of his work in terminology and operative dentistry still underpins modern dentistry. Someone ought to write a book

⁴ Greene Vardiman Black (1836-1915), MD, DDS, ScD, LLD, is considered to be the father of modern dentistry. He was born at Winchester, Ill., in 1836. Dr. Black received his instruction in dentistry under a preceptor, and began practice when he was 21 years of age. He settled in Jacksonville, Ill., in 1864, where he began experimental work in several phases of dental procedures. His work in Jacksonville attracted so much attention in educational circles that, in 1883, he moved to Chicago to accept the Professorship of Pathology in the Chicago College of Dental Surgery. In 1891, he transferred his activities to the Northwestern University Dental School, where he became Professor of Operative Dentistry and Dental Pathology, being made Dean in 1897. He standardized cavity preparation and amalgam manufacture. He laid the foundation for the standardization of dental terminology, and gave the profession the first authoritative work on dental anatomy. His greatest contributions to the professional literature were his volumes on Operative Dentistry and Dental Pathology (12) which went through seven editions. He died from a pernicious anemia, at his boyhood home (a farm near Jacksonville), on Aug. 31, 1915, at the age of 79 (12, 13, 15).

entitled The Scientific Achievements of G. V. Black. These achievements are covered, to some extent, in his biography (13). By the way, Arthur D. Black, the illustrious son of G. V. Black, was the Dean at Northwestern University School of Dentistry for many years. He also had a tremendous impact on dentistry.^{5/}

Another famous researcher who was a native Ohioan, but a graduate of the University of Michigan, was Willoughby Dayton Miller.^{6/} He evolved the theory of dental caries causation which stands today as a proven fact. He postulated that microorganisms in the mouth degrade foods, creating acids which decalcify hard tissues of the tooth. Miller came from around Zanesville, Ohio, and had studied in Germany for a considerable time at Koch's laboratory.

The University of Michigan had a number of notable researchers who served as models for the rest of us. For example, Russell W. Bunting^{7/} was one who

^{5/} Arthur Davenport Black (1870-1937), MD, DDS, ScD, the son of G. V. Black, was Dean of Northwestern University Dental School for 20 years. Like his father, Dean Black was a noted educator, scientist, and writer, having been on the faculty of Northwestern since 1900. At the time of his death, he held a commission as Colonel in the Army Reserve Corps. He was the compiler of the Index of Periodical Dental Literature, consisting of 13 volumes, cataloging dental literature from 1839 to the date of his death; and the author of a classic text on operative dentistry in four volumes and of more than 200 scientific articles in medical and dental literature. As Dean of Northwestern, he established the first dental clinic for children, and organized the first successful department of graduate study in dentistry (3).

^{6/} Willoughby D. Miller (1853-1928), PhD, DDS, MD, a brilliant teacher and researcher, attended the University of Michigan (1870-1875) where he received a BA, followed by study at the University of Edinburgh (1875-1876) and the University of Berlin (1876). He returned to the United States to study dentistry in 1877, and received a DDS from the University of Pennsylvania in 1879. After graduation, he returned to Germany and became a professor of operative dentistry at the University of Berlin. From 1882-1885, he did his most important studies and proposed the main theory of caries causation which is still accepted today: the Chemico-Parasitic (Acidogenic) Theory. He incubated human teeth in a mixture of bread and saliva, producing carious-like lesions (the first artificial mouth!).

The suggestion that microorganisms might be the culprit responsible for tooth decay originated in Germany about 1867. However, not until Miller completed his investigation and published his findings, in 1889, was the etiology of dental caries firmly established. His most widely recognized work on the subject, The Micro-organisms of the Human Mouth (18), became a classic in the bacteriologic literature. Eventually, he returned to the United States as Dean of the College of Dentistry at the University of Michigan. He died on July 27, 1928, of postoperative complications occurring after an operation to treat gangrenous appendicitis (1, 18, 19, 49, 50).

James Leon Williams further expanded our knowledge of dental plaque (2). Williams (1852-1932) was a descendant of Oliver Cromwell, Roger Williams (of Providence), and William Williams (a signer of the Declaration of Independence). In 1871, at the age of 19, Leon Williams was tutored in dentistry under a local dentist, Dr. Roberts, of North Vassalboro, Me. At age 20, he became the youngest member of the Maine Dental Society. He immediately borrowed a microscope which belonged to the Society and began a study of dental histology and pathology of enamel that was to continue for over 50 years. In 1897, at the age of 45, he published an excellent paper describing plaque, stating that acids were localized under plaque against the teeth. He understood well the adhesive nature of plaque (68), and is reputed to have coined the line: "A clean tooth will not decay." He is also remembered for his efforts to improve the aesthetic qualities of artificial teeth. In 1914, he established the selection of artificial teeth on a scientific basis by describing three typical forms of maxillary teeth common to all races (2).

^{7/} Russell W. Bunting (1881-1962), DDS, ScD, FACD, received his DDS and ScD from the University of Michigan in 1902 and 1908, respectively. He served on the faculty at Michigan from 1904 until his retirement. He was Director of Research on Dental Caries, under a grant from the Children's Fund of Michigan (1929-1936); and he then served as Dean of the Dental School (1937-1950). He wrote two books: Oral Pathology and Oral Hygiene and Treatment of Parodontal Disease (10).

was working in caries research, especially helping to delineate the role of carbohydrates in the cause of caries. Moreover, U. G. Rickert ^{8/} was working in therapeutics and pathology, especially as related to root canal pathology. Everyone in dentistry was affected by the research of Dr. Edward Rosenow,^{9/} a microbiologist at the Mayo Institute who suggested a focal infection theory, stating that sepsis from dental disease would serve as a foci of infection for various other diseases and distant target organs throughout the body (37). Another dentist who was a microbiologist in Philadelphia was Joseph L. T. Appleton.^{10/} He helped clarify dentally related infections and their systemic implications (11). Charles F. Bodecker,^{11/} from Columbia University, taught us a great deal about dental caries, hard tissue anatomy, and dental radiography (14, 17).

U. G. Rickert (1874-1938), DDS, MS, FADC, was born in Wadsworth, Ohio, Oct. 22, 1879. After his early years he was a high-school superintendent and science teacher in Atwater, Ohio. In 1901, he entered the University of Michigan, later receiving an MS degree in organic chemistry and bacteriology. He graduated from the College of Dentistry at the University of Michigan in 1916. His outstanding contributions in research were in the field of dental infections in their relation to systemic disease. He was one of the original members of the Council of Dental Therapeutics for the ADA.

Rickert was a keen student of the borderline between medicine and dentistry, and a recognized authority on the diagnosis of general diseases arising from a dental source. During the wave of enthusiasm for the wholesale extraction of teeth for the relief of systemic disturbances, his conservative teachings played a large part in stabilizing thought and practice in this regard.

He died in Chicago on the eve of his 59th birthday, Oct. 22, 1938. His death came wholly without warning, while he was enroute to St. Louis to attend the meeting of the American Dental Association. Passing the time between trains, Dr. Rickert entered a motion picture theater where, sitting alone in a rear seat, he apparently fell asleep and peacefully passed away (4).

^{8/} Even since the early 1900's, when Hunter and Billings introduced the concept of focal infection, that theory became a controversial issue in medicine and dentistry (39). Introduced in a period when bacteriologic methods were crude, the theory was based largely on clinical evidence. However, millions of teeth were needlessly extracted during the time that this controversy existed. Between 1915 and 1930, Edward C. Rosenow, MD, promoted his theory of "elective localization," the predilection of streptococci for specific tissues.

It was widely believed, at that time, that any localized infection was a potential focus and reservoir of infection. The inability of several workers to repeat the experimental work of Rosenow and others, and a more careful consideration of the clinical data as well as controlled studies, raised a great deal of skepticism, with the theory of focal infection falling into disrepute. A critical and comprehensive appraisal of 40 years of documented evidence by the Council on Dental Health of the ADA, in 1951, signified the official end of the era of focal infection (8, 39).

^{10/} Joseph L. T. Appleton, Jr., DDS, ScD, was Dean of the Thomas W. Evans Museum and Dental Institute and the School of Dentistry, University of Pennsylvania (Philadelphia, Pa.), from 1941 to 1951. He was known for a comprehensive (40-chapter) textbook entitled: Bacterial Infection with Special Reference to Dental Practice (11). He received many honors for his research work in bacteriology and pathology.

^{11/} Charles F. Bodecker (1880-1965), DDS, was born in New York City, Sept. 2, 1880. His father, C. F. W. Bodecker, a renowned dental investigator and author, had held a professorship at the University of Buffalo. Young Charles entered the Buffalo University Dental School at age 17, and graduated (in three years) in 1900. Too young to be admitted to licensure, he joined his family in Berlin where he continued his studies in Germany with such illustrious scientists as Heitzmann and Krehl, at the Universities of Berlin and Jena, until 1907. Then he engaged in both practice and research in Berlin until 1923. In the same year, he returned to Columbia University as Chairman of the Department of Oral Histology and Director of Research. He was one of the first two elected members of the IADR, and presented the first report before the Association. He was President of the IADR for the 1942-1943 year.

Percy R. Howe,^{12/} at the Forsyth Dental Infirmary in Boston, was a prime researcher in nutrition and its role in dental caries. He did considerable work on the role of Vitamin C and dental health, and showed that the first visible manifestation of the lack of Vitamin C was the odontoblast. The odontoblast was the first cell in animals and humans which began to show signs of deterioration when the organism was lacking in adequate levels of Vitamin C. In fact, his test was used for years as an assay test for levels of Vitamin C (16).

FORREST: During that period, which non-dentist investigators made the greatest impact on dental research?

PAFFENBARGER: Two investigators were especially important. The first would have to be William J. Gies. In my opinion, no other layman in the world has made a comparable contribution to dentistry. He had a pronounced influence upon dental education, dental research, and dental journalism. He established the first Department of Biochemistry in Columbia University Medical School, and remained there for years. In 1920, when I was a freshman student at Ohio State University, he was Head of Carnegie Institute Survey on Dental Education. I recall seeing this gentleman when the Carnegie inspection group came to our school; but, of course, as a freshman student, I never met him. Although his research was mostly on saliva, he tried to encourage dental research in every possible way.^{13/} He was instrumental in (actually, was the cause of) the

(cont'd.)

Dr. Bodecker's first publication, in 1905, described the colloidin decalcification method and demonstrated the organic matrix of the enamel. He later identified enamel lamellae and enamel rods, sheaths and tufts. He presented evidence that the odontoblastic process was a tube rather than a fiber. He pioneered roentgenographic diagnosis of dental caries and presented the first bitewing x-ray film. He ardently supported prophylactic odontotomy, and his preliminary work helped to establish the DMF caries index, developed later by Henry Klein, and classified dental caries. His death at home on Feb. 17, 1965, was sudden and uncomplicated by illness (17).

^{12/} Percy R. Howe (1864-1950), DDS, LLD, was born in Providence, R.I., on Sept. 30, 1864. He received his DDS in 1889 from Philadelphia Dental College. After graduation, he maintained a successful practice for eight years in Lewiston, Me.--a practice distinguished for ongoing research in bacteriology, histology, and chemistry as these subjects pertained to dentistry. In 1899, he went to Boston to have closer contact with research labs and libraries. In 1914, when the Forsyth Dental Infirmary for Children (the first institution of its type) was dedicated, he was instrumental there in the research laboratory. In 1917, he became the Director of the Forsyth Dental Infirmary, and also served as AIA President (1929-1930). In 1941, he received an LLD from Harvard University (Cambridge, Mass.). His research was in three distinct areas: microorganisms of the human mouth, physiological disturbances induced by nutritional conditions, and the therapeutic treatment of dental caries. He received the ADA's Award of Merit and Achievement in 1945 for his work in the effects of nutritional factors on the teeth. He died, Feb. 28, 1950, in his home in Belmont, Mass. (1).

^{13/} William J. Gies (1869-1948), DDS, DSC, was born in Reistertown, Md., on Feb. 21, 1869. In 1891, he graduated from the College of Wooster (Wooster, Ohio); and in 1897, his PhD at Columbia University. After graduation, he spent many years as Professor of Biological Chemistry at Columbia University. As a non-dentist, he devoted nearly 50 years to dental research, and particularly to the study of saliva and its relationship to dental caries. In 1919, he founded the *Journal of Dental Research*, for 11 years, he edited and prepared it for publication without compensation. He also organized the International Association for Dental Research (IADR), an organization now with worldwide influence in the promotion of dental research. In 1921, under the auspices of the Carnegie Foundation, Dr. Gies engaged in a five-year study of dental education in the United States and Canada. During that time he visited and made a study of over 100 dental schools in both countries. This report was later published in a volume of 692 pages--an amazing undertaking! This study resulted in nearly every dental school becoming associated with a university. He died at age 81, on March 2, 1948, at his home in Lancaster, Pa. (2).

founding of the International Association for Dental Research (IADR). He not only founded the Journal of Dental Research, but also financed it during the Great Depression by borrowing on his life insurance. He was extremely interested in promoting ethical dentistry and in elevating dentistry to a high plateau among the professions (9).

I think that the second most important layman influencing dentistry was my own chief of the U.S. National Bureau of Standards (NBS), Dr. Wilmer Souder (Fig. 6).^{14/} His contributions affected not only dental research and dental education, but the entire profession as well (32, 37, 38).

^{14/} Wilmer Souder (1884-1974), PhD, a physicist and noted dental researcher, was the 12th President of the IADR (1940). He was born, Feb. 21, 1884, in Salem, Ind. He first came to the NBS in 1911 after receiving an MA from Indiana University. In 1916, he received his PhD in Physics and Chemistry (*magna cum laude*) under Professor Millikan and the renowned Nobel Laureate, Albert Michelson, at the University of Chicago. In 1919, the Army Dental Corps asked the NBS to help them in the formulation of some standards for amalgam. The NBS Director, Dr. Samuel W. Stratton, referred this request to Dr. Souder, who was Chief of the Section of Thermal Expansion. Dr. Souder reviewed the literature, consulted with dentists, dental societies, and manufacturers, and came to the conclusion that dentists used a host of materials but didn't understand their physical properties very well. From 1919 to 1922, he and his coworker, Chauncey G. Peters, carried on the research work in amalgam. Then the NBS attempted to enlist the ADA's support for his program. The NBS was not successful, but the Weinstein Research Laboratories offered support, and established a research fellowship that extended from 1922 to 1928. By that time, Dr. Souder had so well demonstrated the need for and the benefit of his program that the ADA expressed a desire to assume the responsibility of the fellowship. Therefore, from 1928 to the present time, the ADA has continued this support.

Dr. Souder also had a distinguished career in criminology. He was an expert in identifying questioned documents, both typewritten and handwritten, and in matching bullets with the guns from which they were fired. He was one of the government's key experts in the famous Lindbergh kidnapping case.

Dr. Souder was a dedicated public servant and a tenacious person, fighting with abandon for the causes in which he believed. In Souder's obituary, Paffenbarger wrote (32):

"Dr. Souder was to appear on the scientific program at the Annual Meeting of the ADA in Dallas in 1924. Many dental manufacturers told the ADA that, if Dr. Souder presented his paper, 'Physical Properties of Dental Materials,' they would withdraw their exhibits. He was met at the train by a leading manufacturer's representative who told him to return to Washington, as he would never be able to give his paper at the Meeting. Dr. Souder replied that, since he was paying for the trip, he would stay and just visit the Meeting. After much discussion among the ADA Board of Trustees, Dr. Souder was invited to present his 'controversial' paper to ADA President William A. Giffon. After hearing it, Dr. Giffon stamped his cane on the floor and said: 'Goddamn it, give it to you lot if it!' Dr. Souder did present his paper, and the manufacturers did not withdraw their exhibits. Times have changed. Today's manufacturers actively participate in all aspects of the specification program."



Figure 6. Dr. William Souder (1884-1974), physicist and noted dental researcher for the U.S. National Bureau of Standards (NBS) [Official NBS photograph]. (Refer to footnote 14/.)

EARLY YEARS AT THE U.S. NATIONAL BUREAU OF STANDARDS
(1929-1942)

CHRISTEN: How did you become a Research Associate for the ADA at the U.S. National Bureau of Standards?

PAFFENBARGER: Well, that's another tale of chance! When I came back to teach at Ohio State University, the Head of the Crown and Bridge Department was Dr. Frank Starr. He had always liked me as an undergraduate student. When I was a dental student, I had become disgusted at Ohio State University because of the lackadaisical training that we received from some of the instructors in the clinic. I decided that, when I returned as an instructor, I was really going to work at improving the situation. As I recall, Dr. Starr was only at the University two half-days a week. So I followed him around all of that time to see how he related to the students. He showed me what he wanted done; and I began to help teach crown and bridge too, even though I had not been assigned to that Department.

Dr. Starr practiced downtown with Dr. Homer C. Brown, who was Chairman of the Scientific Commission and Research Foundation of the ADA. Dr. Brown was also Chairman of the ADA's Legislative Committee.^{15/} In 1928, a Research Fellowship--in which the ADA was involved--had been newly created at the Bureau. The first Research Associate under this Fellowship was Dr. Norris Onslow Taylor, PhD in Chemistry, from the University of Iowa (Fig. 7).^{16/} Dr. Brown wrote to the Bureau, requesting that a dentist be assigned to the staff at the U.S. National Bureau of Standards. After Dr. Starr recommended me, I went to see Brown. He asked if I had had any research experience. I said: "None whatsoever." He then asked if I knew anything about metallurgical research, and I replied: "Not a bit." In good conscience, I couldn't make any pretense of having any knowledge of research. After interviewing another candidate, Dr. Brown told me that he liked me better. I said: "It's more than a question

^{15/} Dr. Homer C. Brown was instrumental in the first dental legislation enacted by Congress in 1931. Thereafter he was responsible for enactment of half a hundred laws, aiding dentists, such as the placing of Dental Corps Officers on an equal basis with Medical Corps Officers. He was President of the ADA in 1913 (5).

^{16/} On Apr. 2, 1928, Dr. Norris Onslow Taylor, Assistant Professor of Chemistry at the University of Iowa (Iowa City, Ia.), reported for duty as the first Research Associate from the ADA at the Bureau.

On Mar. 15, 1978, his son, Dr. Duane Francis Taylor, became Professor of Dentistry at the University of North Carolina, and presided at the fiftieth anniversary of the beginning of cooperative dental research between the ADA and the Bureau.

Dr. Duane F. Taylor was a metallurgist at the Dental Research Section of the Bureau from 1954 to 1961 (38).



Figure 7. Dr. Norris Onslow Taylor, first Research Associate from the American Dental Association at the U.S. National Bureau of Standards. (Refer to footnote 16/.)

of 'like,' Dr. Brown. You've got to have someone with a better scientific background than I have." But Brown stood firm. He said: "I want a dentist over there--someone who knows the dental angle."^{17/}

So, in spite of my protests, Dr. Brown wrote to the Bureau stating that he wanted me to come--and received a somewhat cool reply that they had no need for a dentist. The Bureau people said that they had plenty of consultants, and they would hire a dentist a few half-days a week to meet their requirements. But their answer didn't satisfy Dr. Brown. The Director of the Bureau, Dr. George K. Burgess, happened to be coming to Columbus, Ohio, to address the Chamber of Commerce, so Dr. Brown made an appointment with him and with me to confer backstage. At the meeting, Dr. Burgess stated that, in fact, he had not written the letter declining my services. He knew no details about it, but assumed that it had been written by Dr. Souder.

Dr. Brown was a person who would not be denied. He was a real bulldog. He found out that Dr. Souder was going to give a paper in 1928, in Chicago, at the American Association of Dental Teachers. He told me: "George, I want you to go over there and see Souder." I said: "Fine, but I don't have the money to go." He said: "Well, borrow the money! I'm going to arrange a conference between you with Drs. Arthur Black and Roscoe Volland."^{18/} They are on the Research Commission, and Dr. Souder is going to be there with them."

^{17/}Dr. Paffenbarger has summarized the early growth and development of the relationship between ADA and NBS:

"The American Dental Association has long been interested in conducting and in financing research on, and testing of, dental materials, because of their role in dental health service. What spurred the Association to initiate this activity?--A personality, of course. Dr. Weston A. Price of Cleveland, Ohio, almost singlehandedly founded the Scientific Foundation and Research Commission of the National Dental Association and established its research institute in 1913. It was a misfortune that the research personnel of this institute were drafted during World War I. It never recovered from this shock. However, research support was continued by the American Dental Association through grants-in-aid to many agencies. In 1924, \$600 was appropriated for the Special Bureau of Standards Committee, composed of Drs. Brown, Barber, and Volland. Several meetings were held in 1925 and 1926 with Dr. George K. Burgess, Director of the National Bureau of Standards, and the Honorable Herbert Hoover, Secretary of Commerce, both of whom approved the proposed cooperative program; but it was too late in the year to secure matching Federal funds. However, Dr. Homer C. Brown was not only Secretary of the Scientific Foundation and Research Commission of the American Dental Association, but also Chairman of the ADA Legislative Committee. This Committee was able to persuade the Congress to appropriate \$5,000, earmarked specifically in the Federal Budget of 1926 for dental research at the National Bureau of Standards. In 1927, the ADA succeeded in having this item increased to \$10,000. Then, for 1928, the Association appropriated \$7,500, and the work was under way, with an initial budget of \$17,500." (38)

^{18/}Roscoe H. Volland, DDS, MD, FACP, received his dental and MD degrees from the University of Iowa (Iowa City, Ia.) in 1902 and 1905, respectively. He was a faculty member at the University of Iowa's Dental School for 21 years, and then served 21 more years as Professor of Clinical Dentistry at Northwestern University (Evanston, Ill.), retiring in 1944. He was President of the ADA in 1928, and served as Treasurer of the ADA from 1928 to 1948 (7).

So I borrowed the money and went to Chicago. I heard Dr. Souder give a fine report on his research in dental materials. Afterwards, during our meeting, Dr. Souder said: "We really don't need a dentist at the Bureau. We have part-time dental research associates and we consult with the local dental society when we need to. We have all of the dental consultants that we need." I was on the spot. I said: "I realize that, Dr. Souder; but Dr. Brown said he wants a full-time dentist there, and he made the arrangements for us to get together to discuss the situation. I don't want to embarrass anyone--I think we should go now." Dr. Black said: "Now wait a minute. In my opinion, we should get someone at the Bureau who has metallurgical training. Have you had any training along these lines?" My answer was negative. He said: "Perhaps we should get someone from Northwestern University. We have a course in metallurgy there." "Oh," I replied, "I had a course just like that when I was in school." I explained exactly what we did: We took a piece of steel, cut it into smaller sections, and tempered and quenched it using different methods so that we produced a series of metal pieces, from light-straw to steel-blue. Then we took some steel rods, and filed chisels and dental instruments out of them. By treating them, we produced instruments with differing shank and cutting edge tempers. We used a file to test hardness.

Hence, I said to Dr. Souder: "Even though my background doesn't entitle me to do metallurgical research, I've read the prospectus of Northwestern University, and I've had about the same experience. If you call that qualified, then I am qualified." So Volland said: "Very well, why don't you just go on over there for the summer?" Dr. Souder reluctantly agreed: "We'll just take him for the summer, but beyond that I make no promises." So, on Decoration Day in 1929, I showed up at the National Bureau of Standards in Washington, D.C.

FORREST: What kind of reception did you receive at the Bureau?

PAFFENBARGER: I realized right from the first that I was in a hostile environment. I had been pushed on them by Dr. Brown's persistence. I decided, therefore, that I must maintain a very low profile. I reported to Dr. Souder who told me that my first assignment was to reassemble an interferometer which had been torn down, so that it could be used to produce some interference fringes. I didn't even know what an interferometer was. He said:

"Here are two plates and three pins. I want you to get those three pins the same dimension. Here is a piece of abrasive paper that I want you to fiddle with until you get all three the same dimension. When you look into that eyepiece, you're going to see a series of black and white interference lines."

He patiently taught me how to use the hand micrometer to get some rough measurements. (I didn't even know how to do that! I had had no previous machine-shop experience.) I got the interferometer back together a lot faster than he had anticipated, however, despite my lack of knowledge on the subject.

Being at the Bureau is just like going to graduate school all of the time. We have so many talented people there, with so many disciplines and specialized expertise. I've found that if you're half-way decent, people will go out of their way to assist, advise, or help you. That is one thing that I think is somewhat unique to that institution. People unselfishly allow you

to use their instruments, and coach you on scientific matters. So, for the past 50 years, I have really been going to graduate school, continually doing things I enjoyed but that I was not formally trained to do! Throughout, I have had an ideal working environment.

FORREST: How well-developed was the field of dental materials in those days?

PAFFENBARGER: Fifty years ago, dental materials was practically a new field. I was working for a pioneer in that field, Dr. Souder. He took his doctorate training in physics, and was applying it to dental materials. Let me back up a minute.... My second assignment from Dr. Souder was to survey the various casting techniques which had popped up around the country (21, 44-46). These included various methods: cold mold, water bath, and thermal expansion (Fig. 8). I was given instruments to measure the thermal and setting expansion of the investment, and to measure the thermal changes in the waxes. At that point, Dr. Souder said to Dr. Taylor: "Now we'll have to teach him some metallurgy." So they taught me what a phase and a phase diagram were, how to recognize the various techniques used in getting these constitutional diagrams, and what they meant.

I really worked hard trying to be as fair as I could. I measured the thermal expansion of all these different investments which had been recommended. I tried to make castings that would accurately fit a steel die using these different techniques, but I didn't succeed at all. At the end of the summer, when the project was written up, Dr. Souder was surprised that I could put it all together (21). I even drew illustrations (because I had had mechanical drawing as part of the course at Ohio State University). He was sort of dumbfounded that a dentist could come up with a readable report. At the 1929 ADA meeting in Washington, he told them that he would like to have me on his staff. At the meeting, the Research Commission agreed; and I've been there ever since, except for about five years during World War II, when I was in the Navy.

The ADA granted me a leave of absence (1942-1946) to serve in the U.S. Navy Dental Corps at the Naval Medical Supply Depot in Brooklyn, N.Y.

NAVAL MEDICAL SUPPLY DEPOT (1942-1946)

CHRISTEN: So practically overnight you became a USN dental officer?^{19/}

^{19/} An entry from Dr. Paffenbarger's work diary, dated Saturday, Jan. 8, 1944, states:

"My salary as a Naval Officer has been very good. When I left the National Bureau of Standards I was getting \$5400 annually. My initial pay as a Lt Cmdr was about \$5300. Then, when the Bill was passed that counted Reserve status as Active Service for pay purposes, I obtained about 3 more fogies (5% of base pay for every 3 years of service). Now I was drawing 6 fogies, or 30% of base pay. My salary and allowances then jumped to \$5,926.50. In Nov. 1943, when I was promoted from 2 $\frac{1}{2}$ to 3 stripes, my salary and allowances were raised to a total of \$6,756.50--which is a mighty good salary; and I consider myself indeed lucky to get it in these times."



Figure 8. Dr. Paffenbarger (in 1929), measuring the thermal expansion of dental investment, shortly after he joined the U.S. National Bureau of Standards as a Research Associate for the American Dental Association.

PAFFENBARGER: You're right! I was a Lieutenant Commander, so I reported in a Navy uniform with 2-1/2 stripes of gold braid on my sleeve. I had bought the suit in a men's clothing store in Washington. Neither the clerk nor I knew exactly what a Lieutenant Commander was supposed to wear; but I had a book of instructions, so we figured it out--more or less. At the Union Station in Washington, on my way to New York, I saw a Naval officer who had gold braid on the visor of his cap. Did I give him the dodge! I was scared. What if he asked me some common-knowledge questions about the Navy? What could I tell him? I let him get on the train first, and then I boarded another coach. (You can see how fearful, immature, and gullible I was, even though I was 39 years old at the time.)

When I reported for duty, I found out that I was indeed out of uniform. I was missing some insignia, and others were clearly in the wrong places.

FORREST: With your medical history, how did you pass the physical exam to join the military?

PAFFENBARGER: How I got into the Navy was an interesting and peculiar situation. During the four years I was a student at Ohio State University, I took Army Reserve Officer Training and went to the summer camp at Carlisle Barracks, Pa. After graduation, I stayed in the Reserve, renewing my appointment every five years. In 1939 (15 years following my graduation), when I came up for reappointment in the Army Dental Corps, I asked to be put on active duty because I could see the coming of World War II. I believed that I had special training which might be of real service to the Army. They looked up my record and saw that I had had TB. Then they refused even to give me a physical examination--so I turned down another five-year term in the Reserves.

Then I went to the Navy. I knew Captain Harry Harvey, Chief of the Naval Dental Corps. I informed him that I had quit the Army and I thought I might still be of service to the military. I asked him if the Navy would consider me despite my having had TB. He went in to see Surgeon General McIntyre, who was also the private physician of President Franklin Roosevelt. The Surgeon General said: "We've taken ex-TB's before; and if you want him, we'll have him examined." Captain Harvey had one of the physicians examine me and he reported that I would probably not be a good risk. But Captain Harvey was a determined person. He went to the Surgeon General again and pleaded my case saying: "This is the kind of person we want in the Navy Dental Corps." So the Surgeon General appointed a special three-man board of chest surgeons who went over me from A to Z. They gave me a clear bill of health. They said, however, that I would have to sign a waiver releasing the government of liability should I develop TB while on active duty. I promptly signed it.

CHRISTEN: What was your job like at the Supply Depot?

PAFFENBARGER: After I learned how to get into my uniform properly, I found I was to be involved in setting up a physical testing laboratory and in training personnel to operate it. Our tasks were to prepare specifications for dental materials, call for bids, decide whether 'ersatz' or substitute materials or instruments could be used, and forecast the dental material needs for the Navy. This was no small job, since roughly 800 dental items were listed in the Supply Catalog of the Navy Medical Department. I was not only to do the predicting,

but also to initiate procurement in a timely manner so that no item would be in short supply. I soon found out I was in big business.

After two years of experience, I was beginning to learn the ropes slightly. Here is an entry from my Diary of Jan. 21, 1944: "Tabulated the amount of money that I had obligated from 1 July 1943 to 31 Dec. 1943, and it amounted to roughly \$3.8 millions."

FORREST: Can you recall some specific incidents to show what challenges your job presented?

PAFFENBARGER: There were quite a few. I had been on duty just a few months when the new executive officer approached my desk. (By this time I did know enough to stand up when a 4-striper parked himself beside me!) He wondered how long I had been in the Navy--my answer was "four months." He volunteered that he had been in for 26 years. Did I know many of the officers in the Dental Corps of the Navy? No, I did not. He told me that I would be very disappointed to know that many lazy drunken bums were in the Navy Dental Corps. I replied that this had not been my experience to date; but, if what he said was true, it was an astounding indictment of the Naval Medical Officers who had administered the Dental Corps all these years. "Besides," I said, "I didn't know that physicians had a corner on sobriety." The officer gave a muffled grunt and stalked off. A medical officer (a Commander), whose desk was adjacent to mine, warned me: "You will be transferred tomorrow. You don't know Big John as well as I do!" I told him that it didn't matter to me, since I didn't volunteer to join the Navy to be insulted. I came to do a job.

Nothing happened. Several weeks later, the secretary in the Office of the Commanding Officer, Admiral Melhorn, told me: "I don't know what you told Big John, but you must have done a good job on him because he told our boss that you were the best blankety-blank officer in the whole blankety-blank depot!" I afterwards learned that Big John used this method of finding out if an officer could and would defend himself when disturbed or insulted, and to see if the man could be intimidated. If he couldn't, then Big John had high respect for that individual.

Since I had been in the Army Dental Corp Reserve for 15 years before switching to the Navy, I naturally had kindly feelings for the Army. So I immediately made an effective, but informal, liaison with the Army Medical Procurement Agency. My friend, P. B. Taylor, a physicist, was in charge of the Army's Medical Department Physical Laboratory. We used each other's equipment, and compared notes on rejection of materials. We found out that some unscrupulous contractors switched rejected material from one branch of the Armed Forces to the other. We diverted shipments of common contractors in each category where the Army or the Navy needed material quickly. None of this cooperation was done officially; it was all by word of mouth. Neither he nor I could have effected this cooperation in our Services if we had done things officially. It really paid off. According to my diary entry of Nov. 22, 1945, just in the dental items alone, the Navy obtained 1.3 million dollars of excess Army equipment and the Army took a quarter million dollars of overbought Navy supplies. Otherwise this material would have been purchased on the open market with our tax dollars.

You have no idea how wild some of the estimates for procurement were. In my diary entry of May 27, 1943, I noted that the Navy wanted to buy 12,000 double-ended burnishers for amalgam. The Navy already had 1,000 on stock and 3,000 due on a contract. I just didn't understand what the Dental Corps, with an authorized strength of 1,500 dentists, would do with 16,000 indestructible stellite amalgam burnishers! So I put the matter down in writing and signed my name to the letter. This one little item saved the government \$27,000, which was many times my annual salary. I also found that the Army was paying \$1.60-- and the Navy \$2.82--for the burnishers. I soon corrected this situation.^{20/}

CHRISTEN: What was your role in developing a Federal Supply Catalog for governmental agencies?

PAFFENBARGER: One of the mechanisms we had in the Services in World War II was the "automatic supply table." These supplies went out to the Pacific Area monthly, and were based on 10,000 personnel. Many dental items were in this supply list. When I questioned this practice, the medical officer in charge told me that it need not concern me, since they had good issue rates on which to estimate the needs correctly. "Where did these issue rates come from?" I asked. I was told that they came from the Army, which had a great deal of experience in this matter. In other words, a Navy dental officer was not even going to be allowed to inspect the list of supplies or to make suggestions. I tried to explain that dental supplies were used only by dentists, but that many medical items (like bandages) were used by nonprofessional personnel. I was so persistent that I obtained a copy of the list. It was really ridiculous. Most items were supplied in quantities obviously four or five times more than needed. The selection and numbers of dental burs made no sense, and the proportional amounts of alloy for amalgam and mercury were absurd. I spent several days going over each item, and wrote a detailed explanation of my reasoning.

I further reasoned that, if the dental supplies were sent in such ridiculous amounts, the same was probably true for the medical supplies; so I decided to calculate one item that I could defend, and I chose adhesive tape. I found that the Navy Medical Department was sending 7 sq. ft. of adhesive tape per man per month. These data I incorporated into a second memorandum. As I had anticipated, the 4-stripe medical officer rejected my estimates. So I said: "Captain, if you tended to the medical items and let the dental officer be responsible for the dental items, the government might be a whole lot better off." Before he could counterattack, I added: "Do you know that you are sending 7 sq. ft. of adhesive tape per man per month to the Pacific Area?" He didn't believe it! So I handed him memorandum No. 2 and retreated to my desk. Pretty soon I could tell that he had his warrant officer checking out my figures. Believe it

^{20/} An entry late May 13, 1942, in Dr. Paffenbarger's daily work diary, states: "I just got a letter from the Navy asking for 1200 blowt. inches. We had about 900 in stock and only about 150 in their activities to send them to. The ones we have on hand will supply us for the next year, saving \$6000."

In May 11, 1943, "All day, the letter day, I am under pressure. The work is so heavy, I can't get it done. I have to drive at all times, no letup--just drive, drive, drive. I now have 597 items to take care of, and some new ones are being placed in the catalog."

or not, that afternoon the Captain walked down to my desk and told me that my calculations had proved to be correct. He had the entire list scrutinized, and accepted my estimate for the dental items. Finally, in 1945 or 1946, I was appointed head of an Army/Navy Committee to develop a uniform Federal Supply Catalog for the Medical Departments of the Armed Forces, the VA, Public Health Services, and Indian Health Services.

In those days, the supply situation was in a real mess. Each agency had different nomenclature, stock numbers, packaging requirements, and specifications. Finally, thanks to the War Production Board, the military had a little sense pounded into it by the civilians. In recent years, the Defense Medical Materiel Board has evolved to keep the supply table current. At any rate, a common Supply Catalog was effected and is still in use. I'm very proud of our efforts!

FORREST: You have had a long, fruitful association with and career in military dentistry. In fact, I discovered that you were the first dental officer to attain the rank of Commodore in the U.S. Navy. How did that come about?

PAFFENBARGER: That's a real story in itself! I was a 2-1/2 striper for three years, and then I was automatically selected for Commander. In Nov. 1945, I was promoted to Captain. To my surprise, the Navy had dipped way down into the list to promote me. One Sunday morning, two months later, I was reading the New York Times when I saw a headline on the back of the front page: "RESERVE PEOPLE PROMOTED TO FLAG RANK." I thought to myself, I'll just look down that list--I might know someone. Under the Dental Corps list I saw my name listed as a "Commodore." Well, I thought: My God! Isn't that something! I get notified of a momentous event like this by reading the newspaper! So I called the Commanding Officer, Admiral Melhorn, who said he didn't know anything about it. Then I called the District Dental Officer, but he didn't know anything about the matter either.

I finally found what had happened. The Secretary of the Navy had sent over to the White House the names of all of those people recommended to be promoted to flag rank, and not a single reserve officer was on the list. This was a real problem, since reserve officers comprised about 95% to 97% of the entire Navy officer staff. The President (Truman, I think) said: "That's a hell of a note. There must be some outstanding reservists worthy of promotion." So the President bucked the list back to the Secretary of the Navy to get some reservists on the list. The Secretary of the Navy bumped it back to the various bureaus where the selections were to be made. The Surgeon General had requested the name of an outstanding Reserve Dental Officer, but the Dental Department misunderstood the request. The Department thought that the Surgeon General wanted the name just so he could write a letter of commendation to that officer. The final list made its way back through the Secretary of the Navy to the White House. Truman put his signature on it and called a press conference. So that's how the New York Times had the story before even most of the Navy knew what was happening.

OVERALL PHILOSOPHIES (1924-1980)

CHRISTEN: Do you have any particular impressions as to how dental researchers compare to dentists, in general?

PAFFENBARGER: I think it is very hard to generalize. Let's consider dentists who are in practice....I don't know what the exact percentage would be, but a certain number of dentists are clearly superior. They are superior in their surgical ability, intellect, in fair dealings with others, and in ethical conduct. For purposes of this discussion, let's say this number represents 10%. Now, let's postulate that the 10% at the bottom of the heap are inferior in every way. Then you have the remaining majority, representing all the gradations in between.

Researchers are no different. Of the thousands of dentists and researchers, few make any original contributions to the science or practice of dentistry. That's the way it is with the whole population, whether they be ministers, lawyers, physicians, or ditchdiggers. Each group will have its number of superior people. I don't think you can segregate dental researchers as being basically different from medical or biological researchers or any other specialized research group.

FORREST: You obviously believe that ethical and moral considerations are important for the professional.

PAFFENBARGER: Well, I think the motivation to aid others is one reason that a lot of people enter dentistry or the other healing professions. One is entitled to a reasonably good livelihood in dentistry, but you also have to consider the patient. Your paramount interest is his or her welfare (i.e., when he or she shows up in your office, your diagnosis and treatment should give the same consideration as for your wife, your children, or yourself). The total dental health of the patient must be considered as though it were your own. When you approach the patient with such an attitude, you will never go wrong. Just ask yourself: "What type of care would you like for yourself?" I firmly believe that you can make a living, be a first-rate professional man, and still put your patient's interest paramount.

I think this philosophy is necessary both for the clinician and for the researcher who deal with people at many levels and stations in life. If you treat others fairly, they'll generally make every effort to treat you the same way. You'll always find a few people who will not; but, fortunately, they're small in number. In a like manner, most people do not object to criticism if they think that it is for their benefit. The only time they resent it is when the criticism has an ulterior motive.

CHRISTEN: What have you learned through the years about how to deal with fellow professionals who are difficult to work with?

PAFFENBARGER: Well, I've had some experience along these lines through the years. For example, Dr. Souder had a reputation at the Bureau for being a very difficult man to get along with. He was a very fundamentalist fellow in his religious practice, and belonged to a strict Protestant church. He asked me once if I would come to his church. I agreed. He taught Sunday

School, and I went to his class; but I didn't agree with much of his theology, and I told him so.

He wouldn't allow smoking in his Laboratory. Well, I didn't smoke anyhow, so that didn't make any difference to me! (I smoke occasionally, now.) Moreover, if anyone in the Bureau went to a party and took a cocktail, Dr. Souder might not even say "hello" to that person the following morning because he felt intensely that the individual was damaging his own physical and spiritual health.

After I had been with the Bureau for a few months, I said to him:

"Dr. Souder, you and I have some disagreements and discussions about how people around here live their lives. You know that each person here at the Bureau is different. You've had a different upbringing than I have. For example, your educational experiences have been vastly different from those of mine--and you married a different woman. Our ideas are different on some things." [I decided to pull out all the stops!] "You'll have to tolerate some of my idiosyncrasies and I'll have to tolerate some of yours, but we should never let our differences hinder our friendship or our social feelings toward each other."

That seemed to clear the air because he replied: "Yeah, I guess that's right." However, he could be very pugnacious in expressing his ideas. We kidded him, 'getting in our licks' when we could. For instance, once he put on my desk a clipping that someone had died of cirrhosis of the liver due to alcoholism. I then found my own clipping showing that some president of a women's temperance organization in Baltimore had also died of cirrhosis.

I believe that it helps, simply to say to oneself: "I will not antagonize this person because he holds different beliefs than I do. How can I assume that my position is necessarily the right one in all times and places?" On technical matters, though, I would follow practically everything that Souder said--until I ran into something with which I did not agree. For instance, once I wanted to cut off a little wooden rung with a real fine hacksaw. He kidded me, saying that a real carpenter would never do that. I said: "Here's this rung. You do what a carpenter would do and cut it off. Then let's compare and see who has the best joint." He said: "You've convinced me. I give up."

You see, I was not afraid to talk back to the Chief, but I was never disrespectful. I admired the man tremendously, but he certainly was a different person from me. I simply said to myself: "I must get along with him." Now, it is not a question of pampering nor of bootlicking nor anything of such a nature! He would have resented that. In reality, Dr. Souder wanted employees who had the intestinal fortitude to stand up and fight when they thought they were right.

I'll give you one last example of how I think one should deal with his boss. Once I got into quite a heated dispute with Dr. Souder about policy. Finally, in exasperation, he told me: "Well if you don't agree with me go up and see Mr. Bearce." (Mr. Bearce was one step above him in the organization, and I knew that he and Mr. Bearce did not see eye-to-eye on most matters. I knew, therefore, the Mr. Bearce would decide the matter in my favor on that basis alone.) I said:

"Dr. Souder, I'm not going to go up to see Mr. Bearce, since we both know that you two don't see eye-to-eye and he will likely side with me. Let's settle this question of policy here. You're the Chief of this Laboratory, and you're the one who should run it. When we differ and we can't settle it here, then that's it. I'll assume whatever position you take and, if I can't live with it and can't stand it, then I'll just get another job, that's all."

Dr. Souder said: "Oh, we're not talking about you getting another job!" I answered:

"I'm not threatening to leave; but I say that, if it gets to the point where I can't obey you as the Director of this Laboratory, you then wouldn't want me here and I wouldn't want to be here. But I don't think it's right to take the problems we should be solving to Mr. Bearce."

This was just the way I talked to Dr. Souder. We got along just fine. I think you have to be frank and honest in your dealings.

FORREST: Let's discuss funding for dental research. What is the key to getting money, especially during these times of retrenchment where funds are not as readily available as in past years?

PAFFENBARGER: It is very difficult for a newcomer to obtain money for research. But, if you've been in a laboratory that has produced rather good results over the years, you're at a great advantage. As the number of excellently trained researchers grows and the money available for research dwindles, grants will become more and more selective. I am concerned that a promising young researcher, with no reputation but with great potential, will be 'short-changed' at the expense of older and more established individuals and laboratories (such as ours at the Bureau). The turbine handpiece, composites, spherical amalgams, panoramic x-ray design, and EBA cements--all came out of our laboratory. The writing of ADA standards and specifications was started at the Bureau and has continued over the years (22-26, 29, 30, 41-43, 45-47). The promotion of excellence in dental materials by the writing of standards or specifications defines a satisfactory material through physical and chemical tests in the laboratory. In other words, what we are trying to do is to design laboratory tests that will predict the behavior of the material in the mouth after several years of service. That's one of the contributions of our laboratory. Obviously, when you have a lab with such a background as ours, you're much more likely to receive a research grant than would a lab that's just starting up.

Since everyone has to begin, we must give some money to the people who are just starting their careers.

FORREST: To some, an unfavorable climate for basic research seems to be emerging. I'm thinking, especially, of some government agencies which are willing to sponsor practical research only. How do you contrast the value and relationship between basic and applied research?

PAFFENBARGER: Well, to define and differentiate precisely between basic and applied research is very difficult; for very little basic research doesn't, sooner or later, have application. One has to have the basic knowledge. Consider the

satellites which are spinning around our globe. This basic knowledge of materials, developed throughout the ages (e.g., metals, alloys, composites, ceramics, and combinations thereof; their fundamental properties, etc.), has made satellites possible. If we do not continue to do basic research, then applied research will be greatly limited. Many years ago, for example, when an astronomer was measuring the rotation and the direction of the planets and trying to accumulate all kinds of data about the universe, someone may have asked him: "What good is all this knowledge, and how are we going to apply it?" His reply might very well have been: "I don't know." At the time, his work had very little apparent value. But a time came when we were able to apply his astronomical research.

Congress has recently taken the position that we need to concentrate on applied research. Their view is generally reflected throughout all the government agencies for whom they appropriate monies, including the Armed Forces. But, unless the government and industry support basic research, soon the applied research is going to dry up. In fact, if we don't gain new knowledge, we will not be able to apply that other bit of unused knowledge which was previously acquired; and we will thus be unable to find a useful application.

It's essential that we cultivate--and have a balance between--basic and applied research. Without applied research, this country won't be able to hold the preeminent position in research that it now enjoys.

CHRISTEN: In thinking of the future, how important are the sophisticated new research tools in producing quality results?

PAFFENBARGER: The more sophisticated our instruments, the more we can delve into basic research of physical properties. Let's consider amalgam, as an example. When we treat the amalgam in a certain way, something results. We want to know what causes it to happen. We're going to use the electron microscope and all the new metallurgic techniques, including the electron probe, to determine a small structural part. You can see in the metallograph, by the light that is reflected, that there are different structures. These structures will help you determine its composition. If you know what the causes are, maybe you can circumvent them to some extent and produce a stronger, longer lasting material. So you have to use all the sophisticated methods which are available, and which you have in a large laboratory.

At other times, you can do creditable research without all these instruments. For example, if you want to work with dental waxes, you can do a lot with a simple thermometer. You can conduct a simple flow test, or easily study melting characteristics. Sometimes you have to adapt and use what you have at hand. But, nowadays, you almost have to be associated with a university or agency that has more complete facilities. As time goes on, dental research is becoming more specialized. The researcher is becoming less and less of a generalist. Yet a specialist can become so narrow that he is unable to have a wider vision. That's why we need organizations such as the American Association for the Advancement of Science. This Association provides a forum for the various professions and scientists to gather and to exchange ideas between disciplines (such as the metallurgist, physiologist, pathologist, toxicologist, and various representatives from all the other professions) to supplement each other's knowledge.

CHRISTEN: Who do you feel should actually engage in research? Should it be mainly conducted by especially trained researchers associated with a laboratory that has a bank of sophisticated equipment?

PAFFENBARGER: I think that anyone can do research who has average intelligence, is imaginative, and wants to work hard. One must have the motivation, of course. I'll give you a good example. I had a friend, a physicist at the U.S. National Bureau of Standards, whose father was the engineer who built the Holland Tunnel in New York City. The engineer wanted his son to become a physicist, and sent him to M.I.T. for his doctorate. Thereafter the son went to Heidelberg University, in Germany, for advanced work. The problem was that the son did not want to be a physicist. The son wanted to be a minister! However, his father was a dominant person who was absolutely determined that his son become a physicist. The son went through all those hoops, only to please his father, and eventually ended up at the Bureau. I became acquainted with him both socially and professionally, and discovered that he was not interested in what he was doing at the Bureau. When his father died and left him an estate, he promptly quit his job at the Bureau. He went to Harvard, earned a degree at the Divinity School, and became Pastor of a Congregational Church.

Here was an individual with the finest education that money could buy. He had the intelligence, and plenty of industry; but he was not interested in doing that which his father forced him to do. Finally, he reverted to that which he wanted to do.

CHRISTEN: All areas of endeavor have their frustrating moments. I wonder if you might comment on some frustrations, failures, or disappointments that you have experienced during your career.

PAFFENBARGER: Yes, all I have to do is to read my old research papers to see how many mistakes I have made. It's just like growing up. As a child, you have certain ideas and you put them down on paper as being an absolute truth. Later, as you mature more fully, you realize that your horizons have expanded. You no longer think the same thoughts. When I look over my old papers, I can see crazy ideas that I then propagated which won't 'hold water' now.

At one time, I aspired to become dean of a dental school. In 1938, I heard that Dr. Seamans, who had been Dean at the Dental School at Ohio State University (my alma mater), was retiring. I really wanted that job, and some of my friends contacted several members of the Board of Trustees to lobby on my behalf. These friends arranged for me to travel all through Ohio to lecture before local dental groups to whip up support. Some of the members of the faculty wanted me to be Dean, but others were frankly opposed. When the matter came up before the Board of Trustees, Dean Seamans was against my taking his position. He told the Board that I had a history of tuberculosis, and he didn't think I'd live any longer than four or five years. That was the end of it. They selected a very good man, however, in Wendell D. Postle. Wendell was a personal friend of mine, and he felt chagrined when I was denied the deanship; but I assured him that in no way did I blame him. (Deep in my heart I knew that I was not going to get the job; but, nevertheless, I was very disappointed.)

On another occasion, I wanted to be Secretary of the Council on Dental Research at the ADA; but I didn't get that post either, because Dr. Harold Hillenbrand was against it. He believed I was attempting to undermine him.

Such was not the case. Later, Dr. Hillenbrand became one of my most trusted friends and supporters. He was a great leader who not only supported research but really believed in it. In retrospect, I was far better off in every way by staying at the Bureau. While these were keen disappointments, they did keep me active at the bench level in research activities.²¹

FORREST: Since 1930, you have authored or coauthored over 160 papers on dentally related subjects. You have also coauthored a book, The Physical Properties of Dental Materials, with Wilmer Souder (27). It goes without saying that your work has influenced every aspect of dental research at the Bureau and of dentistry at large. I wonder what you consider to be your greatest contribution to the dental profession?

PAFFENBARGER: Well, I haven't made any great discoveries. The panoramic x-ray, composites, the turbine handpiece, spherical amalgams and EBA cements, and all the other discoveries were done by people other than "George." George didn't do any of that. He did select some of the staff members who did it, however.

I feel that my greatest contributions have been in the development of test methods for evaluating dental materials, and in the formulation of standards and specifications for them for the ADA. This work on dental materials included a close correlation with their clinical performance. I think the finest paper I ever published was with Schoonover and Souder: "Dental Silicate Cements: Physical and Chemical Properties and a Specification" (25). We had a number of papers of this type. To collect the necessary data for them, we purchased every commercially available dental material in a particular class, and then designed tests for properties which seemed pertinent to their clinical usage in dentistry. For example: silicate cements--we were interested in their solubility, optical characteristics (opacity), strength, consistency, setting time, etc. (25). We tried to correlate our information with dental experience. We had a group of clinical dentists who would do experiments in their offices using the products, and report their results back to us. We used this procedure with castings of gold inlays, zinc phosphate cements, hydrocolloidal impression materials, etc. (20, 21, 34-36, 40, 44, 48, 49).

Often we would send unknown or unidentified materials to 'chairside' dentists and ask them to give us their opinions of which of the materials had superior working characteristics. Then we would do the physical and chemical analyses of these materials in our laboratory to see how they matched up with the dentist's

²¹An entry from Dr. Paffenbarger's diary of May 22, 1945, states: "Today I received a letter from the University of Louisville, asking if I would be interested in becoming Dean of their School of Dentistry in 1946-47. Somehow, I just can't get interested."

clinical opinions. Using such criteria, we developed standards. These standards have been accepted throughout the United States and the world.^{22/} Later I became involved in developing international standards (31, 33).

CHRISTEN: What is your opinion concerning the training that dental students are receiving in dental schools today?

PAFFENBARGER: In some ways, the current training is superior to what we received. Most everyone now has at least a baccalaureate degree before going to dental school. This education is certainly broadening. It wasn't long ago that an entire dental college program involved only a three-year course! (I think that type of program ended in 1918. The four-year course began in 1920--with 1924 ending the last four-year program.) I don't know how we could accurately measure the quality of dental service that is currently being rendered for the public against that which was rendered when I graduated.

On the other side of the coin, some people think that the quality of a dental education may actually be poorer now, due to the lessened emphasis on clinical training received in dental school. This deficiency is probably due to the greater emphasis recently placed upon electives, science-oriented courses, and community and preventive dentistry, etc. Unlike medicine, dentistry lacks an internship program; so we need extra emphasis upon clinical training. I strongly suspect that the current student does not have very much practical "hands-on" experience in working on patients prior to graduation. If so, then this is a decided step backward. If I were a dean of a dental school now, I would look at my overall program under a microscope to see if my curriculum actually equipped students to deliver dental health service.

FORREST: How can we motivate dentists to realize the real need for continuing education programs?

PAFFENBARGER: How to motivate and stimulate people who don't want to be motivated and stimulated is one of the major questions confronting our society as a whole. Most people don't seem to want to develop a very high

^{22/} Mrs. Marion P. Kumpula, former Secretary and Administrative Assistant to Dr. Paffenbarger, writes:

"Shortly after World War II, Dr. Paffenbarger was sent to Japan by the Federal Government as one of a team of dentists to assess Japanese dentistry and make recommendations for improving it. As a consequence, his laboratory became a 'Mecca' for Japanese researchers and educators. Later, when he became more involved in international standards for dental materials, the European and South American researchers in his field sought him out. Not only were they welcome in his laboratory, but his home was open to them as well. There he had the perfect partner--a wife who has always been as gracious a hostess as he has been a host. He could call 'Blondie' (Rachel) on a moment's notice, telling her he was bringing a guest home for a meal or for overnight, or for a few days; she could handle any situation. He enjoyed helping his wife prepare for and serve their guests. He is at home in the kitchen, and likes to experiment at something different. Most recently he has been cracking and grinding his own corn to make cornmeal."

degree of self-discipline. If one is really interested, taking the time to continue your education requires no great effort. Unfortunately, more and more, some kind of mandatory continuing education seems probable. The teaching profession offers a precedent for mandatory continuing training. For years, teachers have been required to attend continuing education programs if they wished to maintain their credentials to teach. Their system is beginning to creep into the dental profession already. If people won't discipline themselves, it's likely that someone else will have to do it.

The direction that this continuing education requirement will take is an important consideration. I'm a great believer in continuing education: not just in attending lectures or observing demonstrations, but in getting one's fingers wet in the mouth or working at the laboratory bench. A "do-it-yourself" type of continuing education program is needed. The dentist must be able to observe the patient as a "whole" person--not just deal with a localized situation in the mouth. He must be able to appreciate the necessity for consulting with a patient's physician if systemic problems are observed. He must be able to recognize what's normal and abnormal. If he doesn't know how to take a biopsy, he must be able to refer the patient to someone who can. He should learn the fundamentals of diet, in relation not only to dental health but also to whole-body health. These facets of dentistry are usually extras which have not been adequately taught in college.

CHRISTEN: How do foreign educational goals and strategies compare with those of American dental educators?

PAFFENBARGER: In my opinion, American dental education and dentistry are absolutely superb and seldom equalled by other countries. Scandinavia, Switzerland, The United Kingdom, and Holland produce some excellent dentists and dental researchers. It is remarkable that little countries like Holland or Switzerland can produce such a quantity and quality of dental research. (On a pro rata basis, they put us to shame.)

By and large, those countries which require the MD degree as a prerequisite to dental training are not the leaders in dental research, dental education, or dental practice. Furthermore, I do not think their dental health service is equal to that in those countries where dental education is autonomous.

CHRISTEN: Of the hundreds of awards which you have received throughout the years, which ones are especially meaningful to you?

PAFFENBARGER: Well, I suppose I would take the most pride in receiving the International Award, which is only presented by the Federation Dentaire Internationale (FDI) every five years in honor of Willoughby D. Miller, who is still considered one of the leading dental researchers of all time (refer to footnote 6/). The Award was presented in 1972, by the President of Mexico, Luis Echeverria (Fig. 9), at the meeting of the FDI in Mexico City. I have also received four honorary doctorate of science degrees, in which I take pride. Moreover, I believe that one of my highest honors is to be Rear Admiral (Retired) in the U.S. Naval Reserve Dental Corps. Now, and for the rest of my life, I will prize this honor a great deal (Fig. 10).



Figure 9. Luis Echeverria, President of Mexico (second from left), presenting the International Miller Award to Dr. Paffenbarger (right) at the opening ceremony of the 15th World Dental Congress and the 60th Annual Session of the Federation Dentaire Internationale (FDI), Mexico City, Oct. 22, 1972, while Dr. Harold Hillenbrand (left), President of FDI, looks on.



Figure 10. Rear Admiral George C. Paffenbarger, Washington, D.C., June 13, 1968. [Official photograph]

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INDEX OF NAMES CITED IN TEXT

[Because the entire Review honors Dr. G. C. Paffenbarger, his name is not listed in this "Index." (To locate photographs of him, the reader is referred to the list of "Figures," on pp. 3-4.)]

Appelman, Rachel [Mrs. George C. Paffenbarger] (pp. 16, 17, 40)
Appleton, Joseph L. T., Jr. (p. 20)
Black, Arthur Davenport [son] (pp. 19, 26, 27)
Black, Greene Vardiman [father] (p. 18)
Bodecker, Charles F. [son] (pp. 20, 21)
Bodecker, C. F. W. [father] (p. 20)
Brown, Homer C. (pp. 24, 26, 27)
Bunting, Russell W. (p. 19)
Burgess, George K. (p. 26)
Christen, Arden G. (p. 5; and various "Interview" questions throughout text)
Christen, Joan [Mrs. Arden G.] (p. 2)
Christen, Penny (p. 2)
Christen, Rebecca (p. 2)
Cottrell, Harvey (p. 18)
Echeverria, Luis (pp. 41, 42 [photo])
Forrest, Suzie [Mrs. William R.] (p. 2)
Forrest, William R. [In various "Interview" questions throughout text]
Forziati, Al (p. 8)
Forziati, Florence (p. 8)
Gies, William J. (p. 21)
Giffen, William A. (p. 22)

INDEX (cont'd)

Halberstam, David (p. 2)
Harvey, Harry (pp. 30, 32)
Hillenbrand, Harold (pp. 38, 39, 42 [photo])
Hoover, Herbert (p. 26)
Howe, Percy R. (p. 21)
Klein, Henry (p. 21)
Kampula, Marion P. (pp. 8, 40)
Leahy, Pamela J. (p. 2)
Michelson, Albert (p. 22)
Miller, Willoughby Dayton (pp. 19, 41)
Paffenbarger, Andrew Wolfe (p. 12 [photo])
Peters, Chauncey G. (p. 22)
Postle, Wendell D. (p. 38)
Price, Weston A. (p. 26)
Rickert, Ura Garfield (p. 20)
Roosevelt, Franklin (p. 30)
Rosenow, Edward (p. 20)
Rupp, Nelson W. ["Woody"] (p. 1)
Shaw, Ena Borden (p. 2)
Sippy, Bertram Welton (p. 17)
Souder, Wilmer (pp. 22, 23 [photo], 26-28, 34-36, 39)
Starr, Frank (p. 24)
Steele, Dennis (p. 17)
Steele, Percy (p. 17)
Stratton, Samuel W. (p. 22)
Taylor, Duane Francis [son] (p. 24)

INDEX (cont'd.)

Taylor, Norris Onslow [father] (pp. 24, 25 [photo], 28)

Taylor, P. B. (p. 31)

Truman, Harry (p. 33)

Volland, Roscoe H. (pp. 26, 27)

Williams, James Leon (p. 19)

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